Analysis of Snowmelt Samples Collected from the Cities of Trail and Revelstoke, British Columbia, During the Winter of 1997/1998

B. L. Antcliffe and S. Colwell

Department of Fisheries and Oceans
555 West Hastings Street
Vancouver, British Columbia, V6B 5G3

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ANALYSIS OF SNOWMELT SAMPLES COLLECTED FROM THE CITIES OF TRAIL AND REVELSTOKE, BRITISH COLUMBIA, DURING THE WINTER OF 1997/1998.

by

B.L. Antcliffe[1] and S. Colwell[2]

Department of Fisheries and Oceans
555 West Hastings Street
Vancouver, British Columbia V6B 5G3

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[1] Bio-engineering Support Division
Habitat and Enhancement Branch
Department of Fisheries and Oceans
#360 – 555 West Hastings Street
Vancouver, British Columbia, Canada V6B 5G3

[2] #210 - 7865 Patterson Road
Saanichton, British Columbia, Canada Y8M 2C7

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ABSTRACT

During the winter of 1997/1998, the British Columbia Ministry of Environment, Lands, and Parks and the Department of Fisheries and Oceans conducted a joint snowmelt sampling program to assess the quality of snow ploughed from areas within the Cities of Trail and Revelstoke, located in south-eastern British Columbia. The program was undertaken to evaluate the provincial government's amended snow dumping policy for the Kootenay Region, which prohibits the dumping of "dirty" snow directly into surface watercourses, but allows the dumping of "clean" snow into larger water bodies such as the Columbia River. Five snow samples were collected from each city. They consisted of one control sample (pristine snow collected from an area that was not ploughed, sanded, or salted), two "clean" samples (snow cleared from areas with no more than a light sanding/salting mixture of 20:1), and two "dirty" samples (snow removed from areas where heavy sanding/salting had taken place). The snowmelt was analysed for conductivity, pH, total suspended solids, anions, cations, nutrients, cyanide, total metals, chemical oxygen demand, hydrocarbons, and toxicology. Results indicated that snowmelt quality was highly variable. It was very difficult to distinguish between "clean" and "dirty" snow, and in some cases, the "clean" snow melt samples were more contaminated than the "dirty" samples. Trail snowmelt samples were generally more contaminated than Revelstoke samples, and the Trail samples had elevated concentrations of Al, Cd, Cu, Fe, Pb, and Zn. The Trail lead/zinc smelter likely contributed to the elevated metals in the snowmelt samples. Only one clean and one dirty sample from Trail were analysed for toxicity, however, both these samples were toxic to *Daphnia* and *Selenastrum*, but not *Microtox*. The "clean" sample was in fact more toxic to both *Daphnia* and *Selenastrum* than the "dirty" sample. Toxicity tests conducted on one clean and one dirty sample from Revelstoke showed that these samples were non-toxic to *Daphnia*, *Selenastrum*, or *Microtox*. Recommendations for the regional snow dumping policy and future snowmelt monitoring are made.

RÉSUMÉ

Pendant l'hiver 1997-1998, le ministère de l'Environnement, des Terres et des Parcs de la Colombie-Britannique et le ministère des Pêches et des Océans ont mené conjointement un programme d'échantillonnage de l'eau de fonte de la neige pour évaluer la qualité de la neige ramassée dans certaines zones des villes de Trail et de Revelstoke, dans le sud-est de la Colombie-Britannique. Le programme avait pour objectif d'évaluer la nouvelle politique provinciale de déneigement de la région de Kootenay, qui interdit la décharge directe de neige « sale » dans les cours d'eau, mais autorise la décharge de neige « propre » dans les grandes masses d'eau comme le Columbia. Cinq échantillons ont été prélevés pour chaque ville; ils consistaient en un échantillon témoin (neige vierge prélevée dans une zone où il n'y a eu ni déneigement, si sablage, ni salage), deux échantillons « propres » (neige ramassée dans une zone où avait été effectué seulement un léger sablage/salage dans une proportion de 20:1), et deux échantillons « sales » (neige ramassée dans des zones de fort sablage/salage). On a mesuré dans l'eau de fonte la conductivité, le pH, le total des solides en suspension, les anions, les cations, les matières nutritives, le cyanure, les métaux totaux, la demande chimique en oxygène, les hydrocarbures et la toxicologie. Les résultats ont montré que la qualité de l'eau de fonte de la neige était extrêmement variable. Il était très difficile de distinguer entre la neige « propre » et la neige « sale », et, dans certains cas, les échantillons « propres » étaient plus contaminés que les échantillons « sales ». Les échantillons de Trail étaient en général plus contaminés que ceux de Revesltoke, et présentaient des concentrations élevées de Al, Cd, Cu, Fe, Pb et Zn. C'est vraisemblablement à la fonderie de plomb/zinc de Trail que l'on peut attribuer les fortes teneurs en métaux des échantillons de neige. Pour Trail, l'analyse de la toxicité a été effectuée seulement sur un échantillon propre et un échantillon sale; les deux se sont révélés toxiques pour *Daphnia* et *Selenastrum*, mais non pour *Microtox*. L'échantillon « propre » était en fait plus toxique pour *Daphnia* et *Selenastrum* que l'échantillon « sale ». Les tests de toxicité effectués sur un échantillon propre et un échantillon sale provenant de Revelstoke ont montré une absence de toxicité pour *Daphnia*, *Selenastrum* et *Microtox*. Des recommandations sont présentées au sujet de la politique régionale de déneigement et de la surveillance future de l'eau de fonte de la neige.

1.0 INTRODUCTION

The Cities of Trail and Revelstoke are both situated near the Columbia River, located in south eastern British Columbia (B.C.). These cities often receive large volumes of snow during a normal winter season. Both cities have historically disposed of cleared snow from downtown core and other areas by dumping it primarily into the Columbia River, or in the case of stockpiled road snow, at various dry land sites in or just outside of town limits.

In B.C. there is no official provincial policy per se guiding the discharge of snow into surface watercourses. However, the federal *Fisheries Act* and provincial *Waste Management Act* both apply. The *Fisheries Act* prohibits the discharge of deleterious substances into fish bearing waters, as well as any harmful alternation, disruption, or destruction of fish habitat. The *Waste Management Act* provides the Regional Waste Manager and the Ministry with the authority to issue orders if it is deemed that pollution may occur or is occurring due to any activity.

In 1996, the BC Ministry of Environment, Lands, and Parks (BCMELP) requested the co-operation of the municipalities and highway contractors in reducing the impact of road snow disposal on surface waters in the Kootenay Region. They requested that snow ploughed and removed from roadways not be deposited in rivers, creeks, or lakes. Most municipalities were able to modify their historical snow disposal practices in order to meet this request. The cities of Trail and Revelstoke were unable to meet this request. One reason was that Trail had a record snowfall year in 1996, and could not find enough suitable space for dry land disposal of snow. The City of Revelstoke claimed that the high cost of trucking snow to dry land disposal sites further away from the city prohibited this option.

In 1997, the BCMELP developed a regional snow dumping policy in consultation with the cities of Trail and Revelstoke, to help guide municipalities in the Kootenay region. The regional policy prohibits the discharge of snow into sensitive habitat such as small streams and lakeshores. It allows the discharge of "clean snow" into larger water bodies, such as the Columbia River, under the assumption that clean snow will not be classified as a deleterious substance under the federal *Fisheries Act*. It also prohibits the dumping of dirty snow into any type of watercourse.

In response to this policy, the Department of Fisheries and Oceans (DFO) requested that a snowmelt sampling program be conducted to determine whether "clean" snow can be separated from "dirty" snow on the basis of snowmelt sample quality, and whether "clean" snow is deleterious. This program was designed jointly by the BCMELP and DFO, and implemented during the winter of 1997/1998. This paper presents the methods and results of this snowmelt sampling program for the Cities of Trail and Revelstoke. Recommendations for revisions to the regional snow dumping policy, and further snowmelt sampling during the winter of 1998/1999, are made.

2.0 METHODS

A total of five snowmelt samples were collected from each city (Trail and Revelstoke) during the winter of 1997/1998. The set of five samples consisted of: one control sample (defined as pristine snow collected from roads outside the city which were not ploughed, sanded, or salted), two "clean" snow samples (defined as snow of no more than a light sanding/salting of a 20:1 sand/salt mixture), and two "dirty" snow samples (defined as snow removed from streets where heavy sanding/salting had taken place). In the interest of practicality, snow removed from the downtown core, high traffic areas (e.g., highways and bus routes), and steeply inclined main thoroughfares, was classified as dirty snow.

Sampling locations for the five samples collected from Trail are shown in Figure 1. Some of the sampling sites and the snow disposal sites are also shown in the photographs in Appendix 1. A description of the sampling locations, sample type (control, clean, dirty), and other information (e.g., estimated number of sanding/salting events per sample), are shown in Tables 1A and 1B for Trail and Revelstoke, respectively.

Table 1: Sample number, type, location, and other information for all snow samples collected from the city of Trail during the winter of 1997/1998.

No.	Type	Location	Date	Time	No. of snow-falls	No. of sanding/ saltings	No. of days of rain	No. days on ground
1	Control (I1173)	Pople Park (Shavers Bench)	12/16/97	9:30	2	0	1 - morning	1
2	Clean (I1506)	# 2970 Highway Dr.	1/05/98	8:45	4	1 or 2	0	3
3	Dirty (I1707)	# 785 Binns St.	1/14/98	10:30	4/5	5 ±	1 or 2 ±	3
4	Dirty (I1869)	Bailey St/ McKelvie Dump	1/19/98	10:45	4/5	5 ±	3	4
5	Clean (I2151)	Birch Ave. 1000 blk.	1/30/98	15:10	7 ±	2 or 3 ±	5 or 6 ±	21 ±

Note: The sample number in the above table is shown in Figure 1, and it indicates the location where the sample was collected.

Table 2: Sample number, type, location, and other information for all snow samples collected from the city of Revelstoke during the winter of 1997/1998.

No.	Type	Location	Date	Time	No. of snow-falls	No. of sanding/ saltings	No. of days of rain	No. days on ground
1	Control (I1548)	Vacant Lot (2nd & Orton)	1/05/98	9:00	1	-	-	1/4
2	Clean (I2034)	2nd St. @ City Hall	1/14/98	07:45	1	1	-	1/4
3	Clean (I1706)	Col. R. snow dump (dry land area)	1/26/98	11:00	1	1	2 ±	2
4	Dirty (I2249)	Illecill. snow dump	2/02/98	14:30	1	2 ±	8 to 12	8 to 14
5	Dirty (I2395)	Col. R. snow dump (dry land area)	2/09/98	10:00	2 ±	> 4	> 4	≈ 12

Snow samples were collected by filling a 57 L Nalgene container using a clean, non-metallic shovel. The lid to the Nalgene container was then placed over the sample and secured with tape. The cylinder was transported to a heated room and placed near a heater to facilitate melting. The date and time was recorded. The sampled was checked regularly, and the date and time of complete melting was also recorded. In order to distribute the sample from the large Nalgene container into the smaller sample bottles provided by the laboratory, the original sample was well-mixed by rotating the Nalgene container with the lid securely fastened. A small amount of sample was then allowed to pass through the spigot at the base of the container. This sample was discarded, and then the sample bottles were filled. The 57 L snow sample provided approximately 15 to 20 L of melt water.

The individual sample bottles were packed in a cooler with ice packs and shipped to one of the following three laboratories: ASL for general chemistry (pH, conductivity, total suspended solids, anions, cations, nutrients, hydrocarbons, chemical oxygen demand,

cyanides, and metals); the Environment Canada Pacific Environmental Science Centre for toxicology (*Microtox*, *Daphnia*, and *Selenastrum*); or JR Labs for bacteriology.

All chemical analysis for conventional parameters in water were carried out by ASL Laboratories following procedures described in "Methods for Chemical Analysis of Water, Wastewaters, Sediments, and Biological Tissues", and /or "Standard Methods for the Examination of Water and Wastewater". Metals were analysed by an ICP-OES scan, using procedures adapted from "Standard Methods for the Examination of Water and Wastewater", 19th Edition, 1995. Samples were analysed for extractable hydrocarbons using procedures adapted from the U.S. EPA Methods 3510/8015, 3rd. Edition, Washington, D.C., and the B.C. Ministry of Environment, Lands and Parks Method for "Extractable Petroleum Hydrocarbons in Water by GC/FID", January 1996. All toxicity tests were conducted at the Environment Canada PESC Laboratory using Environment Canada protocols. Further details are available upon request.

Since toxicity testing was performed on only two of the five samples collected for each city, and the rainbow trout toxicity test was not performed, a toxic unit analyses was performed on all samples to predict whether the samples may have been acutely toxic to adult rainbow trout. The methods for the toxic unit model that was applied are described in Duncan and Antcliffe (1996).

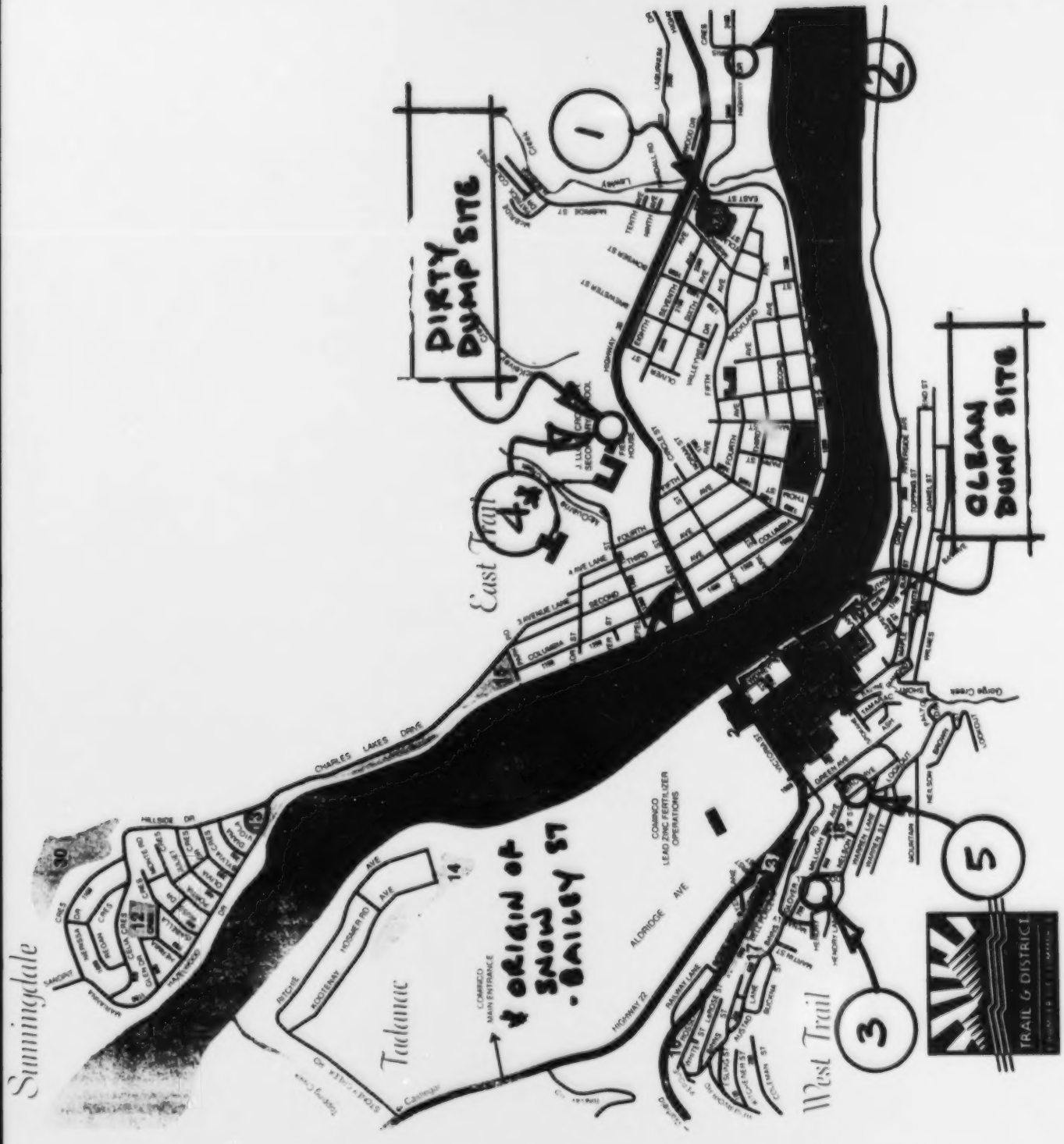

Figure 1. City of Trail - location of "clean" and "dirty" snow dump sites, and location where the five snowmelt samples were collected.

3.0 RESULTS

Analytical chemistry and toxicology results for all snowmelt samples collected are shown in Appendix 2A for the City of Trail and Appendix 2B for Revelstoke. Chemistry results for the City of Trail were plotted graphically to show differences between clean and dirty samples, relative to the control sample (Figures 2 to 7). Results of the toxic unit analysis are presented in Appendix 3A and 3B for Trail and Revelstoke, respectively. A series of photographs are also presented in the section following the references.

Results are discussed below, separately for Trail and Revelstoke.

3.1 Trail

The control sample had non-detectable, or otherwise very low concentrations of dissolved anions, nutrients, weak-acid dissociable cyanide, total extractable hydrocarbons, chemical oxygen demand, total metals, and total suspended solids (TSS). Conductivity was low, and pH was 5.46. The control sample was collected from Polpe Park - Shavers Bench (Photo. #1), which is an area that is not ploughed, sanded, or salt.

The two "clean" sampled collected at Trail were highly variable in terms of the snowmelt quality. The first clean sample (No. 2 - I1506), which was collected from Highway Drive, was very contaminated. The approximate area where this sample was collected is shown in Photo. #2. This sample was similar in quality to the first dirty sample (No. 3 – I1707), collected from Binns St., which is a bus route (see Photo. #3). This first clean sample was also much more contaminated than the second clean sample (No. 5 – I2151), collected a residential area on Birch Avenue (approximate location shown in Photo. #4). Conductivity for this first clean sample collected was higher than for any of the other samples, including the two dirty snow samples, as was the concentration of sodium, chloride, and sulphate. Metals were also elevated. Concentrations of iron, aluminum, copper, cadmium, strontium, vanadium, titanium and silicon were much higher in this first clean sample than in the second clean sample, and they were as high or higher than the first dirty sample collected on January 14, 1998. TSS was 492 mg/L in the first clean sample collected, compared to 217 mg/L for the second clean sample, and 826 mg/L and 1030 mg/L for the first and second dirty samples, respectively.

Like the clean samples, the two dirty samples collected from Trail exhibited variable snowmelt quality. The second dirty sample (No. 4 – I1869) was the most contaminated, which is not surprising since this sample was collected from the McKelvie Dump site (shown in Photo. #5). This is the land site where the "dirty" snow is dumped. The first dirty snow sample from Trail was less contaminated, and on average, somewhat similar to one of the clean samples collected. This dirty sample was not collected from a dump site, but from a street along a busy bus route.

The toxicity results for snow samples collected from Trail indicated that the first clean sample (from Highway Drive) was non-toxic to *Microtox* (a bacterium), but very toxic to *Daphnia* (a water flea), and *Selenastrum* (a green alga). The first dirty sample was also non-toxic to *Microtox*, but very toxic to *Daphnia*, and moderately toxic to *Selenastrum*. The first clean sample was in fact slightly more toxic than the first dirty sample, as indicated by the percent mortality results in the 48 hr. *Daphnia* test (67% for the clean sample and 57% for the dirty sample), and the *Selenastrum* results (72 hr. IC50's of 9% and 87% for the clean and dirty samples, respectively). The second clean sample and second dirty sample were not tested for toxicology.

The toxic unit model works on the concept that a sample with a total toxic unit of less than 1 is unlikely to be acutely toxic to the test organism, while samples greater than 1 are likely to be toxic. In this case we used adult rainbow trout as the test organism because it is a standard toxicity test, even though other species or life-history phases could be used. The results of the toxic unit analyses indicated that the control sample had a total toxic unit of 0.95. Hence, this sample should not be toxic. The chemical analyses support this prediction from the toxic unit model.

The first clean sample had a total toxic unit of 48.7, which would imply the sample would be acutely lethal to rainbow trout. The toxicology results indicated that this sample was toxic to *Daphnia* and *Selenastrum*. The second clean sample had a total toxic unit of 15.16. Since the total toxic unit for this sample was greater than 1, the model predicts that it would be acutely lethal to rainbow trout. However, the sample may or may not be acutely because total metal concentrations were used in the analysis, and it is the dissolved fraction that primarily contributes to acute toxicity, as well as the form that the metal is in. Also, the model's assumption of additivity may not apply. Environmental variables such as pH, hardness, and temperature also affect toxicity. This sample was not tested for toxicology.

The toxic unit model predicted that both of the dirty samples from Trail would be acutely - lethal to rainbow trout. The first dirty sample collected was toxic to *Daphnia* and *Selenastrum*, and chemical results indicated it was contaminated. The second dirty sample was the most contaminated as evidenced by the chemical results, and although no toxicity testing was completed, the toxic unit model and chemical results suggest that this sample would have been acutely lethal to trout.

In February, 1998, a reconnaissance was taken of the foreshore area where so-called "clean" snow has been dumped into the Columbia River at Trail. This site is shown in Figure 1 as the "Clean Dump Site", and in Photo's #7, and 8. A close-up of the substrate at this dump site is shown in Photo's #9 and 10. The photographs indicate that there was a build-up of find sediment and sand on the bank and river bottom where the snow had been dumped. Over time, continual dumping will lead to a built of sediment, contaminants, and refuse typically associated with street snow, that may harmfully alter, destruct, or temporarily disrupt fish habitat. Section 35(2) of the *Fisheries Act* prohibits dumping,

and we therefore recommend that all efforts be made to dump heavily silted and contaminated snow on dry land.

3.2 Revelstoke

The control sample was similar to that collected at Trail in that it had non-detectable, or otherwise very low concentrations of dissolved anions, nutrients, total extractable hydrocarbons, chemical oxygen demand, total metals, and total suspended solids (TSS). Conductivity was also low, and pH was 5.2. This control sample was collected from a vacant lot, and thus had not been ploughed, sanded, or salted.

The snowmelt quality was relatively clean for the "clean" and "dirty" samples collected from Revelstoke. As for Trail, one of the so-called "clean" samples collected from Revelstoke was generally more contaminated than the dirty samples. TSS was very high (3400 mg/L) for the second dirty sample (No. 5 – I2395), collected from the Columbia River dump site, in the dry land area. The location of this dump site is shown in Photo. #11 and 12.

The snowmelt quality for the samples from Revelstoke was much better than those collected from Trail. The samples had lower concentrations of most contaminants tested, with the exception of high TSS concentrations in one sample from Revelstoke.

Toxicity testing indicated that the first clean sample (No. 2 – I2034) and the first dirty sample (No. 4 – I2249) were non-toxic to *Microtox*, *Daphnia*, and *Selenastrum*. The first clean sample was collected from the Columbia River snow dump dry land area, and the first dirty sample from the Illecillewaet River snow dump, location shown in Photo. #6. The other clean and dirty samples, and the control, were not tested for toxicity.

The toxic unit model indicated that the highest total toxic unit (of 10.21) was recorded for the first dirty sample, which was tested and shown to be non-toxic to *Microtox*, *Daphnia*, and *Selenastrum*. Even though the toxic unit was greater than 1, it is difficult to extrapolate this analysis to rainbow trout toxicity, for reasons discussed in Antcliffe and Duncan (1996). However, the concentrations of contaminants were low, and the total toxic units for all samples were much lower than at the Trail site.

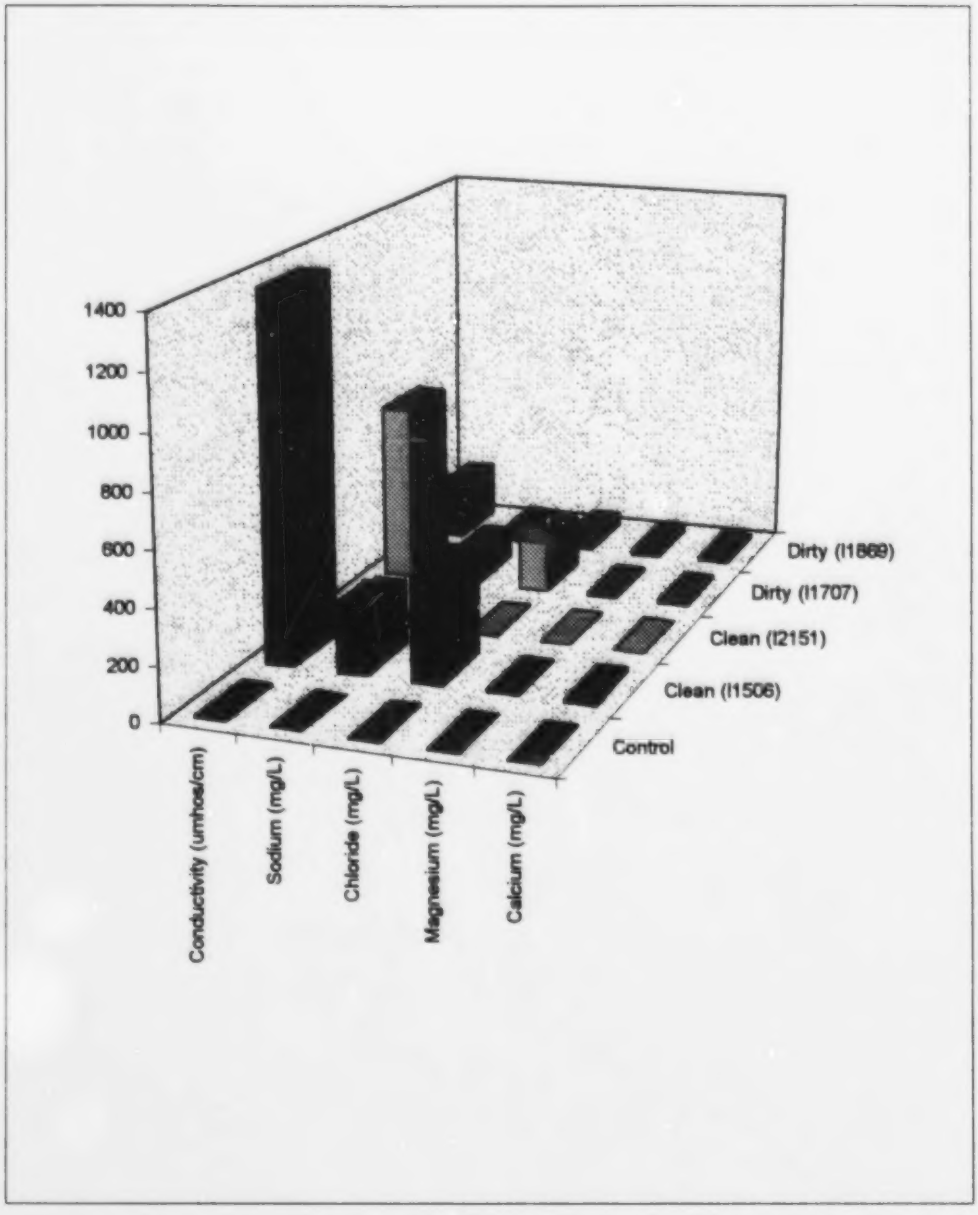

Figure 2. Conductivity, sodium, chloride, magnesium, and calcium concentrations in snowmelt samples collected from Trail during the winter of 1997/1998.

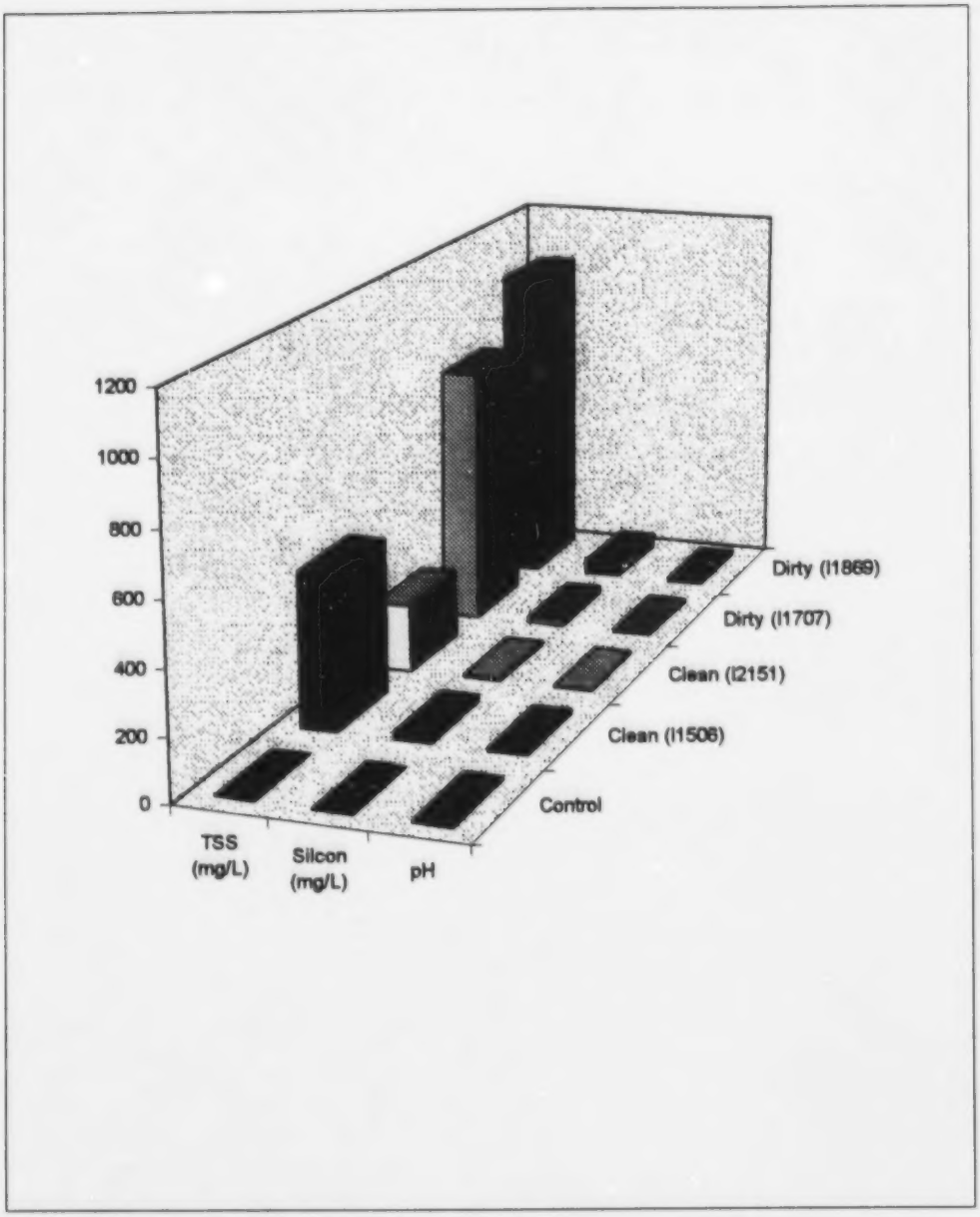

Figure 3. Total suspended solids, silicon, and pH results for snowmelt samples collected from Trail during the winter of 1997/1998.

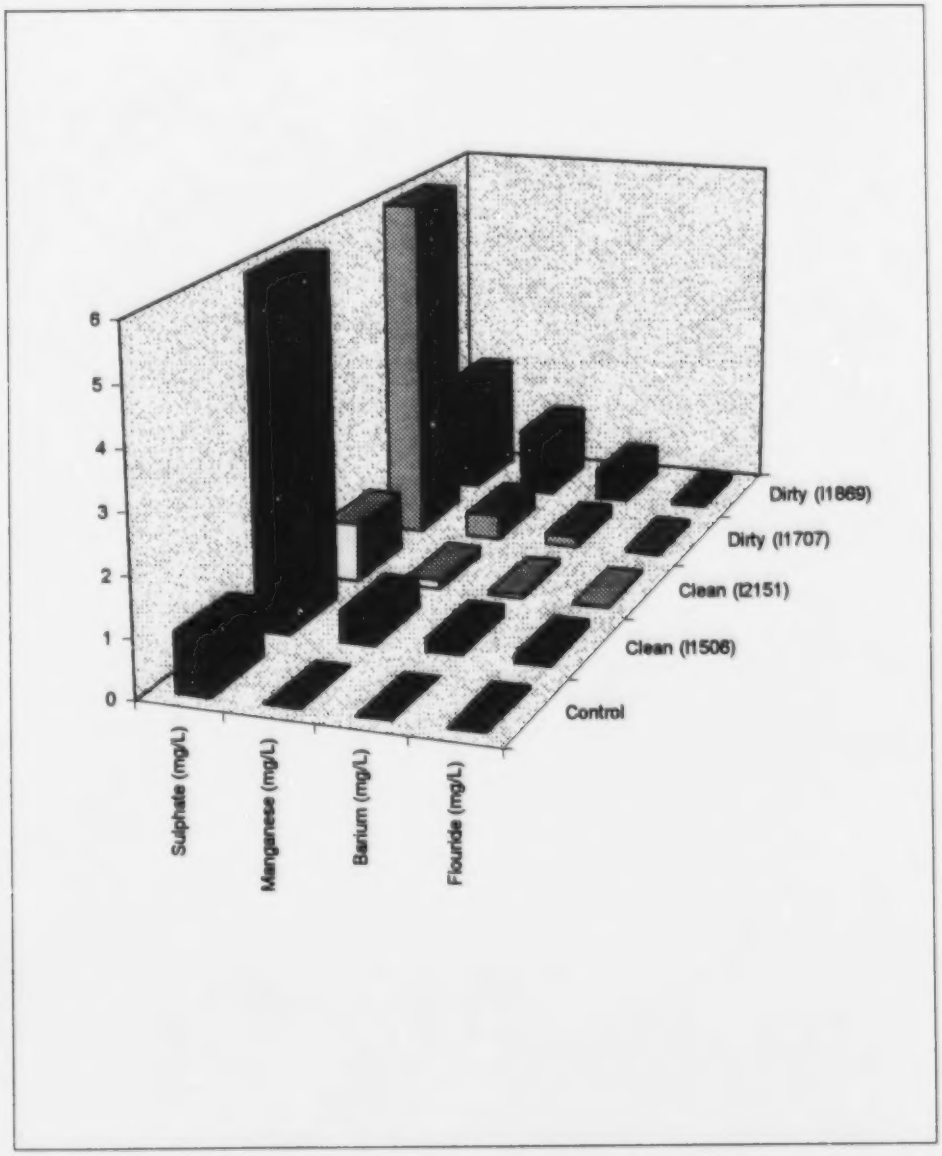

Figure 4. Sulphate, manganese, barium, and flouride concentrations in snowmelt samples collected from Trail during the winter of 1997/1998.

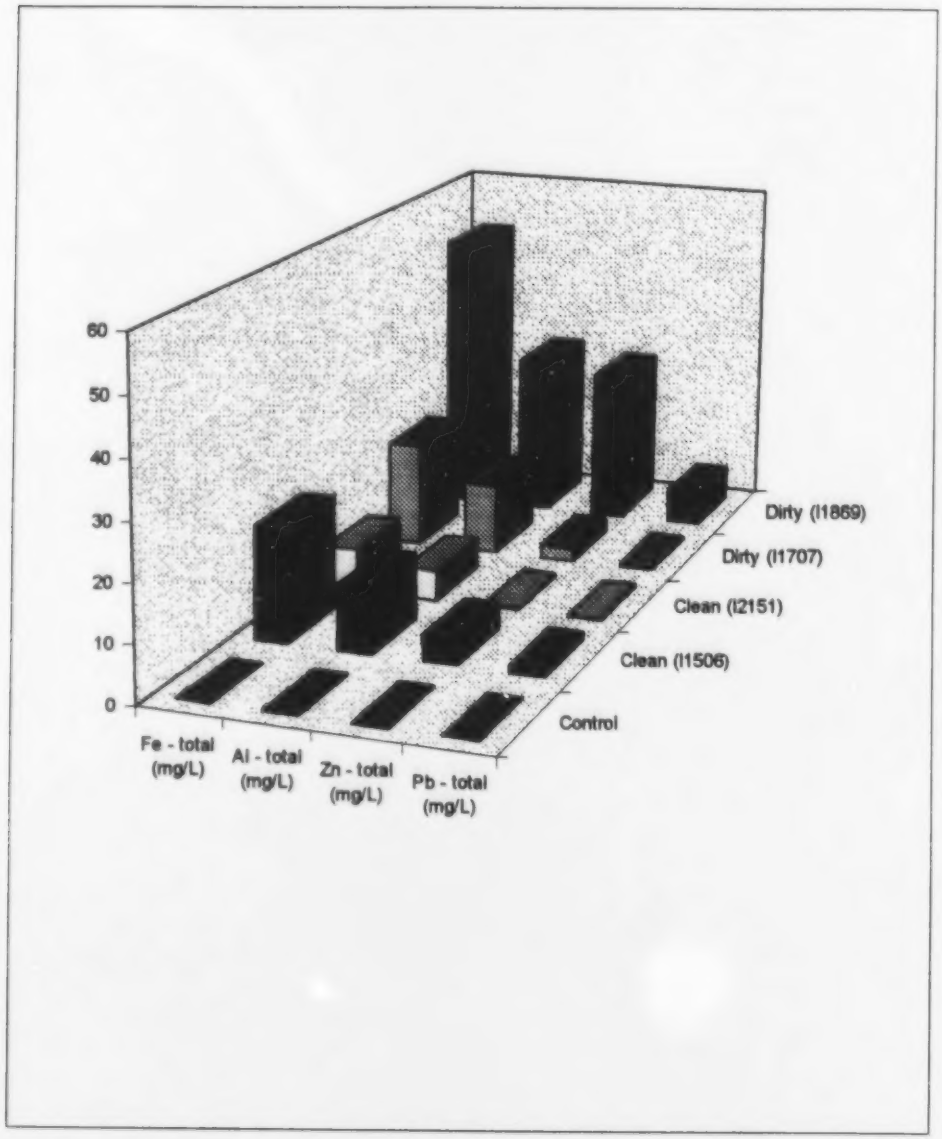

Figure 5. Concentration of total iron, total aluminum, total zinc, and total lead in snowmelt samples collected from Trail during the winter of 1997/1998.

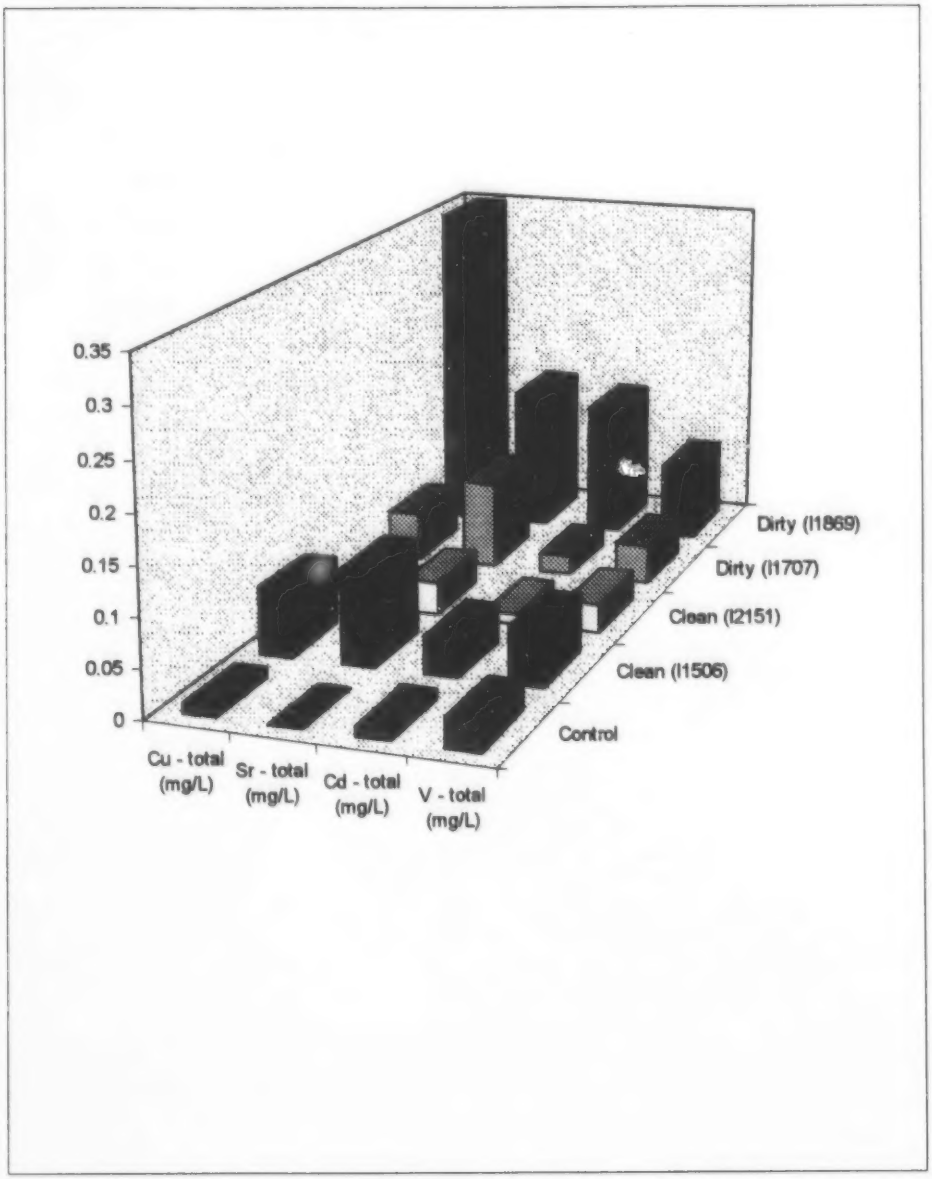

Figure 6. Concentration of total copper, total strontium, total cadmium, and total vanadium in snowmelt samples collected from Trail during the winter of 1997/1998.

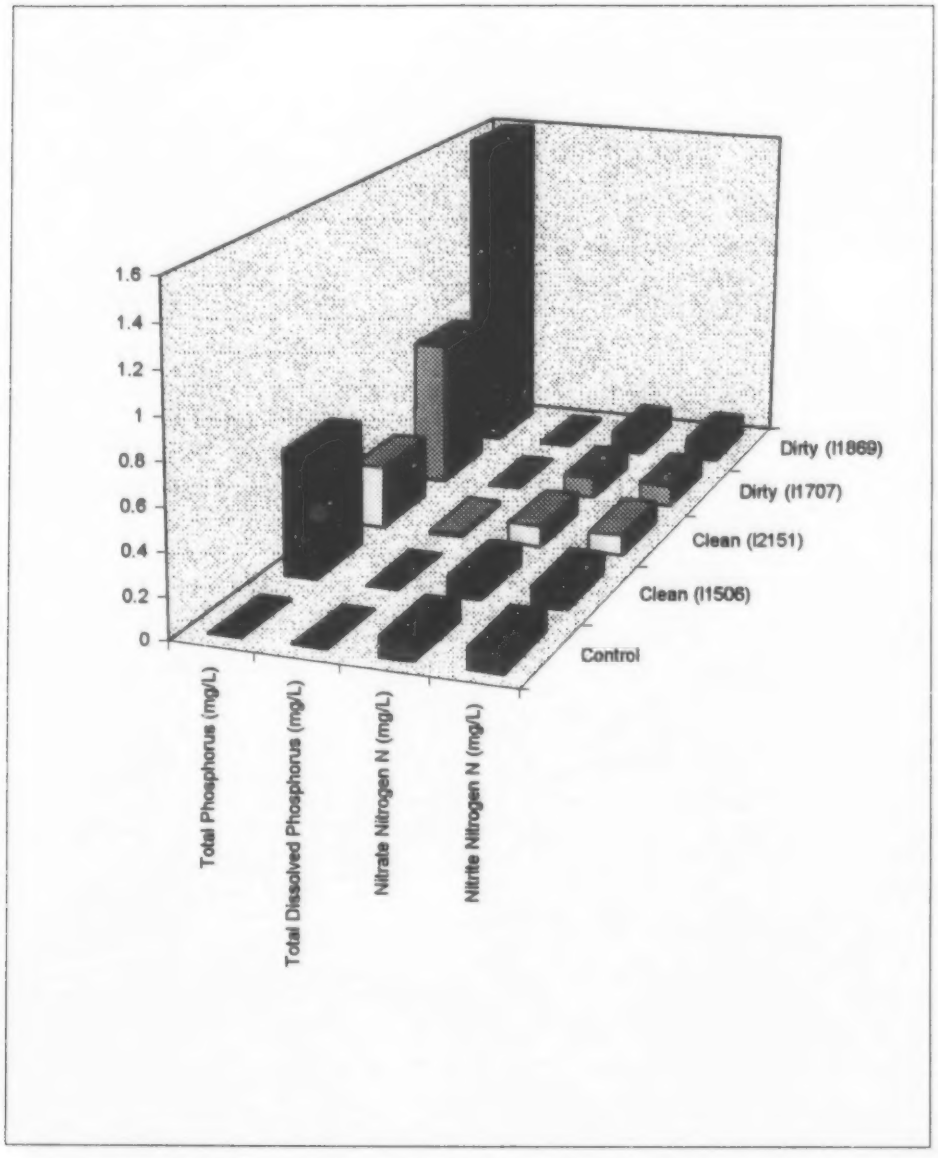

Figure 7. Concentration of total phosphorus and total dissolved phosphorus in snowmelt samples collected from Trail during the winter of 1997/1998.

4.0 DISCUSSION

The control samples for both cities contained virtually non-detectable concentrations of metals, hydrocarbons, dissolved anions, nutrients, and WAD cyanide, indicating areas of pristine snow that has not been influenced by sanding, salting, heavy traffic, or other activities.

The toxicity of the clean and dirty samples from the City of Trail appeared to be due mainly to metals and TSS. The key metals detected in the snowmelt samples were aluminum, cadmium, copper, iron, lead, and zinc. These metals may be associated with atmospheric deposition from the lead/zinc smelter located in downtown Trail. This would explain why the snowmelt quality for the City of Trail was much worse than that for the City of Revelstoke, which is not directly influenced by smelter or other industrial emissions. The reason why the control sample collected from Trail had low concentrations of these key metals may be related to the fact that the control sample was collected after being on the ground for only one day, and it was influenced by rain only for a few hours in the morning before the sample was collected. All of the other samples collected from Trail remained on the ground for at least 3 days prior to sampling, and they were comprised of a larger number of snowfalls and rain events.

Nutrient concentrations were low for all samples collected, and they were similar to control values. Weak-acid cyanide was less than the detection limit of 0.005 mg/L at all sites, with the exception of the control site at Revelstoke, where it was 0.022 mg/L. This may be an analytical error, but the concentration is still low. Cyanide was included in the testing program as some anti-caking compounds contain cyanide.

Results from both Trail and Revelstoke show that snowmelt quality is highly variable, and that it can be difficult to separate or distinguish "clean" from "dirty" snow. For example, one of the "clean" samples from Revelstoke was more contaminated than one of the "dirty" samples from this city. At Trail, the first clean sample was more toxic and the dirty sample, and very highly contaminated with salts and metals (and similar in quality to the first dirty sample collected from Trail). When this sample melted the sampler noted that there was considerable scum on the sides of the Nalgene container as the snow melted. Since this sample was collected from the #2 bus route (a high traffic area), it could have been better classified as a "dirty" sample, rather than "clean" sample. Dirty snow samples were defined as snow removed from streets where heavy sanding/salting had taken place, such as the downtown core and high traffic areas, including bus routes. If this is the case, then it may be possible to conduct further testing to distinguish between "clean" and "dirty" snow areas for the City of Trail.

Despite the issue over labelling and characterisation of clean versus dirty snow, results did show considerable variation in snowmelt quality among sampling location. For example, Figure 2 shows the wide range in values for conductivity, sodium, and chloride in each

sample. Other authors have also found the concentration of various contaminants in snowmelt water to be variable (Scott 1980). This variability may prevent further characterisation of clean versus dirty snow.

The concentration of total suspended solids (TSS) was high for several snowmelt samples. The TSS concentrations for the first and second dirty samples collected from Trail were 826 mg/L and 1030 mg/L, respectively. The TSS for the second dirty sample collected from Revelstoke, at the Columbia River dump site, was 3400 mg/L. These high concentrations may be related to sanding and salting activities, storage time on the ground, rainfall, and freeze-thaw cycles. It is also possible that these TSS concentrations were underestimated, for example if some of the solids settled or stuck to the sides of the Nalgene container prior to transfer into the individual sample containers. TSS is deleterious to fish as it can clog fish gills and impair feeding due to cloudy water. Settled solids can smother spawning habitat, fish eggs, and food organisms. We therefore do not support the dumping of any type of snow with elevated TSS concentration into watercourses frequented by fish, or into fish habitat.

Although the toxic unit model was applied and indicated that several of the samples collected from Trail may have been acutely lethal to rainbow trout, it is very difficult to predict acute toxicity to all fish or other aquatic organisms. Actual bioassays should be conducted to confirm toxicity predictions.

5.0 RECOMMENDATIONS

5.1 Regional Snow Dumping Policy

Results showed that it was difficult to distinguish between clean and dirty snow, especially for the City of Trail. Snowmelt quality and toxicity were also variable. Thus, even though the snowmelt quality for the City of Revelstoke was much cleaner than that from Trail, the best option in all cases is to dispose of ploughed snow at dry land sites. This will prevent deposition of deleterious substances into fish bearing waters, and harmful alteration or disruption of fish habitat as a result of deposition of fine sediment, chemical contamination, or disposal of other garbage or litter associated with street snow.

For the City of Revelstoke, the snowmelt quality was relatively good for clean snow. It may therefore be possible to adopt the amended regional policy at this location. The dirty snow, however, should always be dumped on land as it will undoubtedly have high TSS concentration, and possibly other contaminants. In the past it has been possible to dump snow in the dry land area located only 200 to 300m away from the site where snow is dumped directly into the Columbia River (see Photo. #13). This option should be further explored in the future, to maximise the dry land disposal of both dirty and clean snow.

The amended snowmelt policy is unsuitable for the City of Trail at this point because results indicate it is difficult to separate clean from dirty snow, and both clean and dirty

snowmelt samples were contaminated and toxic to various aquatic organisms. Given that the one "clean" snow sample that was very contaminated may have been collected from a "dirty" site (bus route), further testing could be conducted to determine if clean snow areas could be separated from dirty areas. Although the local smelter may adversely affect snowmelt quality for both "clean" and "dirty" snow types, the new smelter should actually improve the quality of snowfall in the Trail area. It may also be possible to separate out clean snow by collecting it as soon it falls to the ground, thereby reducing the number of snowfall and rainfall events that affect the snow sample. If further testing indicated that clean snow areas could be distinguished, and that such snow was not deleterious to fish and other aquatic biota, then the amended policy could be re-considered, provided it would not lead to harmful alteration or disruption of fish habitat. Obviously the best choice environmentally is to identify additional dry land disposal sites to accommodate the disposal of both clean and dirty snow.

5.2 Snowmelt Monitoring

We recommend that future snowmelt monitoring programs include the rainbow trout acute toxicity test, along with the *Daphnia* and *Selanastrum* bioassays. Sample volumes for the trout test could be reduced by running the LT test, as opposed to the LC50 test. The *Microtox* test did not show any toxicity for the various snowmelt samples collected.

Future monitoring should include dissolved metals rather than, or in addition to, total metals, because it is the dissolved form that primarily contributes to acute toxicity. Further testing should also include TSS, as concentrations can reach levels of concern for the protection of fisheries resources.

Future testing should also focus on characterisation of so-called "clean" snow, rather than dirty snow (areas with heavy sanding or salting), since dirty snow has been, and should continue to be, dumped on dry land.

6.0 ACKNOWLEDGEMENTS

We would like to thank the Ministry of Environment, Lands, and Parks, Nelson, B.C., for their support and participation in this study. Specifically, Julia Beatty-Spence and Rick Crozier contributed to the study design and reviewed draft reports. We are grateful to the Cities of Trail and Revelstoke for their participation in the snowmelt sampling program. Mr. Thom Volpatti, an Engineering Technician with the City of Trail, and Mr. Gordon Hall, an Engineering Technician with the City of Revelstoke, are thanked for their participation and collection of snow melt samples.

7.0 REFERENCES

Duncan, B., and B.L. Antcliffe. 1996. Toxicity Assessment of Effluent From the Cominco Metallurgical and Fertilizer Operations at Trail, B.C. Internal Report. 34p.

Scott, W.S. 1980. Occurrence of Salt and Lead in Snow Dump Sites. *Water, Air, and Soil Pollution* 13(1980): 187-195.

APPENDIX 1: Photographs

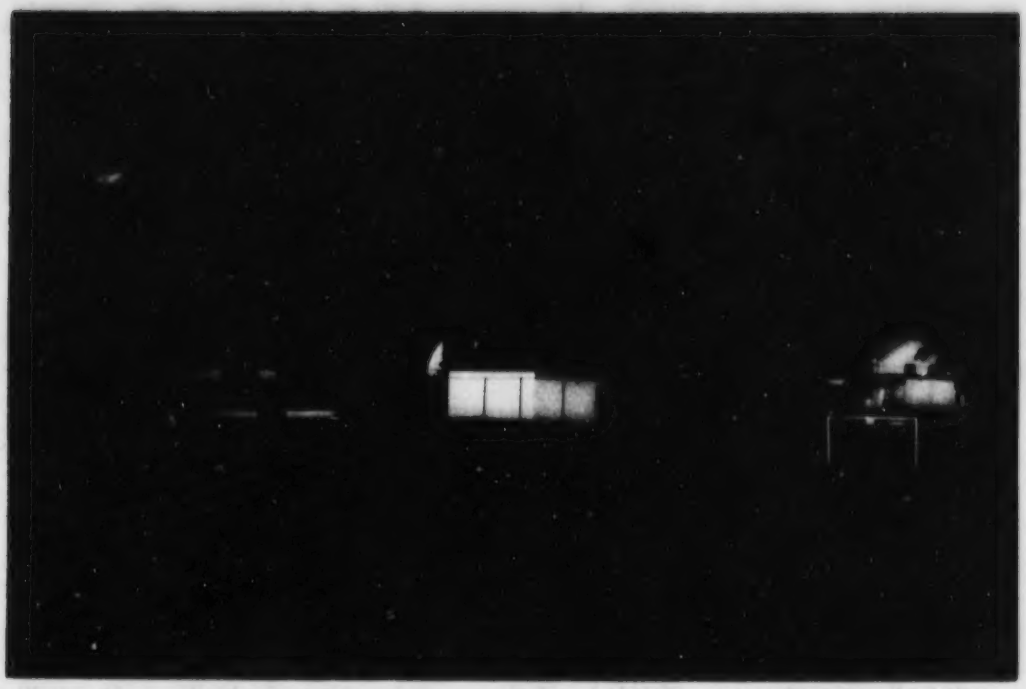

Photo. #1: Trail – Location where sample No. 1 (I1173 – control) was collected.

Photo. #2: Trail – Location where sample No. 2 (I1506 – "clean" snow) was collected. This street is a major bus route.

Photo. #3: Trail – Approximate location where sample No. 3 (I1707 – "dirty" snow) was collected. This street is a bus route.

Photo. #4: Trail – Approximate location where sample No. 5 (I2151 – "clean" snow) was collected.

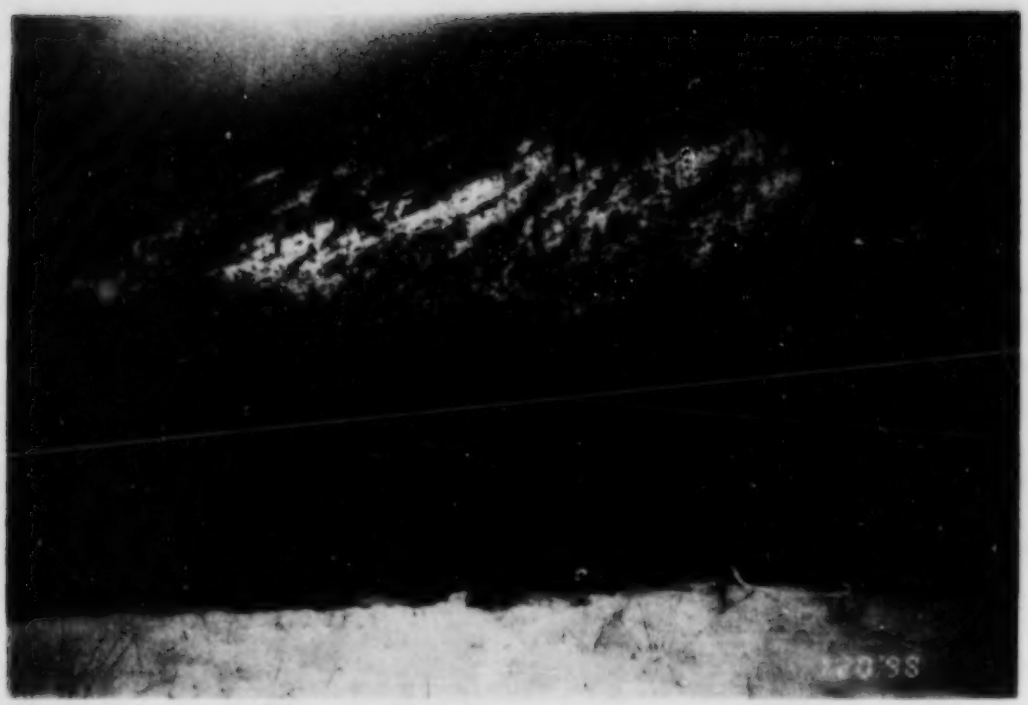

Photo. #5: Trail – Dirty snow land disposal site (also called McKelvie dump site). Shows location where sample No. 4 (I1869 – "dirty" snow) was collected.

Photo. #6: Revelstoke – Illecillewaet River land disposal site, located at 4th St. Bridge

Photo. #7: Trail – Clean snow disposal site to the Columbia River. Gate is opened and trucks dump snow over the edge into the Columbia River

Photo. #8: Trail – Clean snow disposal site to the Columbia River. Shows location where snow is dumped onto the bank river, and into the Columbia River.

Photo. #9: Trail – Clean snow disposal site to the Columbia River. Shows build-up of fine sediment in the substrate, and clean gravel (no fines) in the background

Photo. #10: Trail – Clean snow disposal site to the Columbia River. Shows build-up of fine sediment in the substrate, and clean gravel (no fines) in the background

Photo. #11. Revelstoke – Clean snow disposal site to the Columbia River. Trucks back up to concrete bumper and dump when Columbia River water levels are high enough to allow snow to flow downstream.

Photo. #12: As in Photo. #11 – view from Columbia River.

Photo. #13: Revelstoke – The dry land, clean snow disposal site is located to the left of this photo, about 200m to 300m from the Columbia River clean snow disposal site shown in Photo. #11 and 12. This site is used when the Columbia River water levels are too low to allow dumped snow to flow down the Columbia River.

APPENDIX 2A: Snowmelt Data for Trail Collected During the Winter of 1997/1998.

Sample No.:		I1173	I1506	I2151	I1707	I1869
Sample Type:		Control	Clean	Clean	Dirty	Dirty
Variables - all units in mg/L unless specified otherwise						
Conductivity umhos/cm		4	1360	23	663	202
PH		5.46	6.58	6.23	6.71	8.05
TSS		<1	492	217	826	1030
Bromide (Br)		<0.5	<0.5	<0.5	<0.5	<0.5
Chloride Cl)		<0.5	396	2.6	189	48.8
Fluoride (F)		<0.02	0.12	<0.02	0.06	0.1
Sulphate (SO4)		<1	6	<1	6	2
Nitrate Nitrogen N		<0.1	0.1	<0.1	0.1	<0.1
Nitrite Nitrogen N		<0.1	<0.1	<0.1	<0.1	<0.1
T-Diss.Phosphate P		0.004	0.002	0.016	0.002	0.006
Aluminum	T-Al	<0.2	11.7	5.4	12.5	28.6
Antimony	T-Sb	<0.2	<0.4	<0.2	<0.2	<0.2
Arsenic	T-As	<0.2	<0.4	<0.2	<0.2	<0.2
Barium	T-Ba	<0.01	0.22	0.07	0.19	0.55
Beryllium	T-Be	<0.005	<0.01	<0.005	<0.005	<0.005
Bismuth	T-Bi	<0.1	<0.2	<0.1	<0.1	<0.1
Boron	T-B	<0.1	<0.2	<0.1	<0.1	<0.1
Cadmium	T-Cd	<0.01	0.04	<0.01	0.02	0.14
Calcium	T-Ca	<0.05	12.9	3.56	10.4	17
Chromium	T-Cr	<0.01	0.02	<0.01	0.02	0.08
Cobalt	T-Co	<0.01	<0.02	<0.01	0.01	0.03
Copper	T-Cu	<0.01	0.07	0.02	0.05	0.35
Iron	T-Fe	<0.03	20	7.62	18.6	50.5
Lead	T-Pb	<0.05	1.2	0.4	0.49	6.08
Lithium	T-Li	<0.01	<0.02	<0.01	0.02	0.03
Magnesium	T-Mg	<0.05	7	2.56	6.55	17.1
Manganese	T-Mn	<0.005	0.53	0.159	0.428	1.18
Molybdenum	T-Mo	<0.03	<0.06	<0.03	<0.03	<0.03
Nickel	T-Ni	<0.02	<0.04	<0.02	0.03	0.05
Phosphorus	T-P	<0.3	<0.6	0.3	0.7	1.6
Potassium	T-K	<2	7	<2	4	8
Selenium	T-Se	<0.2	<0.4	<0.2	<0.2	<0.2
Silicon	T-Si	<0.05	21.2	10.4	18.6	44.1
Silver	T-Ag	<0.01	<0.02	<0.01	<0.01	<0.01
Sodium	T-Na	<2	241	3	116	36
Strontium	T-Sr	<0.001	0.099	0.034	0.093	0.149
Thallium	T-Tl	<0.1	<0.2	<0.1	<0.1	<0.1
Tin	T-Sn	<0.03	<0.06	<0.03	<0.03	<0.03
Titanium	T-Ti	<0.01	0.97	0.4	1.05	2.15
Vanadium	T-V	<0.03	<0.06	<0.03	0.04	0.08
Zinc	T-Zn	0.006	4.59	0.67	2.31	27

APPENDIX 2A: Continued.

Sample No.: Sample Type:	I1173 Control	I1506 Clean	I2151 Clean	I1707 Dirty	I1869 Dirty
Total Extractable Hydrocarbons (C10 - 30)	<1	<1	<1	<1	<1
Chemical Oxygen Demand (COD)	<20	159	20	127	126
Weak Acid Dissociable Cyanide	<0.005	<0.005	<0.005	<0.005	<0.005
Toxicity Tests:					
Microtox 5 minute IC50		>100%		>100%	
Microtox 15 minute IC50		>100%		>100%	
Daphina 48 hr LT50@100% conc.		24h<LT50<48h		24h<LT50<48h	
Daphina 48 hr % mortality @100% conc.		67%		57%	
Selenastrum 72 hr IC50		9%		87%	

APPENDIX 2B: Snowmelt Data for Revelstoke Collected During the Winter of 1997/1998.

Sample No.:		I1548	I2034	I1706	I2249	I2395
Sample Type:		Control	Clean,	Clean	Dirty	Dirty
Variables - all units in mg/L unless specified otherwise						
Conductivity umhos/cm		5	4	31	7	14
PH		5.2	6.21	5.71	6.13	7.64
TSS		<1	127	30	216	3400
Bromide (Br)		<0.5	<0.5	<0.5	<0.5	<0.5
Chloride (Cl)		<0.5	<0.5	6	1.2	<0.5
Fluoride (F)		<0.02	<0.02	0.03	<0.02	0.02
Sulphate (SO4)		<1	<1	2	<1	<1
Nitrate Nitrogen N		0.1	<0.1	0.1	<0.1	<0.1
Nitrite Nitrogen N		<0.1	<0.1	<0.1	<0.1	<0.1
T-Diss.Phosphate P		0.003	0.002	0.003	0.257	0.037
Aluminum	T-Al	<0.2	1.4	0.4	4.4	0.8
Antimony	T-Sb	<0.2	<0.2	<0.2	<0.2	<0.2
Arsenic	T-As	<0.2	<0.2	<0.2	<0.2	<0.2
Barium	T-Ba	<0.01	0.03	0.01	0.05	1.09
Beryllium	T-Be	<0.005	<0.005	<0.005	<0.005	<0.005
Bismuth	T-Bi	<0.1	<0.1	<0.1	<0.1	<0.1
Boron	T-B	<0.1	<0.1	<0.1	<0.1	0.1
Cadmium	T-Cd	<0.01	<0.01	<0.01	<0.01	<0.01
Calcium	T-Ca	0.07	1.21	0.3	1.26	53.9
Chromium	T-Cr	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	T-Co	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	T-Cu	<0.01	<0.01	<0.01	0.01	<0.01
Iron	T-Fe	<0.03	2.42	0.63	7.4	0.63
Lead	T-Pb	<0.05	<0.05	<0.05	<0.05	<0.05
Lithium	T-Li	<0.01	<0.01	<0.01	<0.01	0.04
Magnesium	T-Mg	<0.05	0.7	0.17	1.94	20.3
Manganese	T-Mn	<0.005	0.11	0.063	0.201	0.052
Molybdenum	T-Mo	<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	T-Ni	<0.02	<0.02	<0.02	<0.02	<0.02
Phosphorus	T-P	<0.3	<0.3	<0.3	<0.3	<0.3
Potassium	T-K	<2	<2	<2	<2	2
Selenium	T-Se	<0.2	<0.2	<0.2	<0.2	<0.2
Silicon	T-Si	<0.05	1.83	0.58	6.8	3.8
Silver	T-Ag	<0.01	<0.01	<0.01	<0.01	<0.01
Sodium	T-Na	<2	<2	4	<2	33
Strontium	T-Sr	<0.001	0.006	0.006	0.01	0.51
Thallium	T-Tl	<0.1	<0.1	<0.1	<0.1	<0.1
Tin	T-Sn	<0.03	<0.03	<0.03	<0.03	<0.03
Titanium	T-Ti	<0.01	0.12	0.02	0.27	0.02
Vanadium	T-V	<0.03	<0.03	<0.03	<0.03	<0.03
Zinc	T-Zn	0.007	0.028	0.01	0.044	<0.005

APPENDIX 2B: Continued.

Sample No.:	I1548	I2034	I1706	I2249	I2395
Sample Type:	Control	Clean,	Clean	Dirty	Dirty
Total Extractable Hydrocarbons (C10-C30)	<1	<1	<1	<1	<1
Chemical Oxygen Demand (COD)	<20	22	<20	<20	159
Weak Acid Dissociable Cyanide	0.022	<0.005	<0.005	<0.005	<0.005
Toxicity Tests:					
Microtox 5 minute IC50		>100%		>100%	
Microtox 15 minute IC50		>100%		>100%	
Daphina 48 hr LT50 @ 100 conc.		non-toxic		non-toxic	
Daphina 48 hr % mortality @ 100% conc.		7%		0%	
Selenastrum 72 hr IC50		>100%		>100%	

APPENDIX 3A: Acute Toxicity Units for Trail Snowmelt Samples.

	One Toxic Unit	Trail I1173 Control		Trail I1506 Clean		Trail I2151 Clean		Trail I1707 Dirty		Trail I1869 Dirty	
	mg/L	*mg/L*	*toxic units*	*mg/L*	*toxic units*	*mg/L*	*toxic units*	*mg/L*	*toxic units*	*mg/L*	*toxic units*
Cd*	0.01	0	*0.00*	0.04	***4.00***	0	*0.00*	0.02	***2.00***	0.14	***14.00***
Tl	0.5	0.1	*0.20*	0.2	*0.40*	0.1	*0.20*	0.1	*0.20*	0.1	*0.20*
Cu	0.07	0.01	*0.14*	0.07	***1.00***	0.02	*0.29*	0.05	*0.71*	0.35	***5.00***
Zn	0.3	0.006	*0.02*	4.59	***15.30***	0.67	***2.23***	2.31	*7.70*	27	***90.00***
Cr	4.4	0.01	*0.00*	0.02	*0.00*	0.01	*0.00*	0.02	*0.00*	0.08	*0.02*
Fe	10	0.03	*0.00*	20	***2.00***	7.62	*0.76*	18.6	***1.86***	50.5	***5.05***
Pb	0.5	0.05	*0.10*	1.2	***2.40***	0.4	*0.80*	0.49	*0.98*	6.08	***12.16***
Al	0.5	0.2	*0.40*	11.7	***23.40***	5.4	***10.80***	12.5	***25.00***	28.6	***57.20***
Se	4.2	0.2	*0.05*	0.4	*0.10*	0.2	*0.05*	0.2	*0.05*	0.2	*0.05*
Ni	2.5	0.02	*0.01*	0.04	*0.02*	0.02	*0.01*	0.03	*0.01*	0.05	*0.02*
As	11	0.2	*0.02*	0.4	*0.04*	0.2	*0.02*	0.2	*0.02*	0.2	*0.02*
Fl	3	0.02	*0.01*	0.12	*0.04*	0.02	*0.01*	0.06	*0.02*	0.1	*0.03*
Na	500	2	*0.00*	241	*0.48*	3	*0.01*	116	*0.23*	36	*0.07*
Total:			*0.95*		***49.2***		***15.2***		***38.8***		***183.8***

Notes:
Cd - value set to zero if less than detection limit
Bolded values are greater than one toxicity unit
Toxic Units are based on dissolved concentrations, however concentrations used are totals, as worst case scenario

Toxicity Test Results:	I1506	I1707
Microtox 5 min. IC50	>100	>100%
Microtox 15 min. IC50	>100%	>100%
Daphina 48 hr. LT50 @ 100%	24h<LT50<48h	24h<LT50<48h
Daphina 48 hr. % mortality @ 100%	67%	57%
Selenastrum 72 hr. IC50	9%	87%

APPENDIX 3B: Acute Toxicity Units for Revelstoke Snowmelt Samples.

	One Toxic Unit	Revel. I1548 Control		Revel. I2034 Clean		Revel. I1706 Clean		Revel. I2249 Dirty		Revel. I2395 Dirty	
	mg/L	*mg/L*	*toxic units*	*mg/L*	*toxic units*	*mg/L*	*toxic units*	*mg/L*	*toxic units*	*mg/L*	*toxic units*
Cd*	0.01	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*	0	*0.00*
Tl	0.5	0.1	*0.20*	0.1	*0.20*	0.1	*0.20*	0.1	*0.20*	0.1	*0.20*
Cu	0.07	0.01	*0.14*	0.01	*0.14*	0.01	*0.14*	0.01	*0.14*	0.01	*0.14*
Zn	0.3	0.007	*0.02*	0.028	*0.09*	0.01	*0.03*	0.044	*0.15*	0.005	*0.02*
Cr	4.4	0.01	*0.00*	0.01	*0.00*	0.01	*0.00*	0.01	*0.00*	0.01	*0.00*
Fe	10	0.03	*0.00*	2.42	*0.24*	0.63	*0.06*	7.4	*0.74*	0.63	*0.06*
Pb	0.5	0.05	*0.10*	0.05	*0.10*	0.05	*0.10*	0.05	*0.10*	0.05	*0.10*
Al	0.5	0.2	*0.40*	1.4	***2.80***	0.4	*0.80*	4.4	***8.80***	0.8	***1.60***
Se	4.2	0.2	*0.05*	0.2	*0.05*	0.2	*0.05*	0.2	*0.05*	0.2	*0.05*
Ni	2.5	0.02	*0.01*	0.02	*0.01*	0.02	*0.01*	0.02	*0.01*	0.02	*0.01*
As	11	0.2	*0.02*	0.2	*0.02*	0.2	*0.02*	0.2	*0.02*	0.2	*0.02*
Fl	3	0.02	*0.01*	0.02	*0.01*	0.03	*0.01*	0.02	*0.01*	0.02	*0.01*
Na	500	2	*0.00*	2	*0.00*	4	*0.01*	2	*0.00*	33	*0.07*
Total:			*0.96*		*3.7*		***1.4***		***10.2***		***2.3***

Notes:
Cd - value set to zero if less than detection limit
Bolded values are greater than one toxicity unit
Toxic Units are based on dissolved concentrations, however concentrations used are totals, as worst case scenario.

Toxicity Test Results:	I2034	I2249
Microtox 5 min. IC50	>100%	>100%
Microtox 15 min. IC50	>100%	>100%
Daphina 48 hr LT50 @ 100%	non-toxic	non-toxic
Daphina 48 hr % mortality @ 100%	7%	0%
Selenastrum 72 hr. IC50	>100%	>100%